

INSTRUCTION MANUAL
FOR
WIDE BAND ROTALYZER

TEST EQUIPMENT CALIBRATION
BRANCH
A.E.E.L. - N.A.D.C.

INSTRUCTION MANUAL

THE ROTALYZER

Table of Contents

	Page
Section I Introduction	1
1.1 Purpose	1
1.2 Specifications	1
1.3 General Description of Equipment	2
1.31 Tachometer Head	2
1.32 Analyzer	2
1.33 Oscilloscope	3
Section II Operating Instructions	3
2.1 Placing in operation and checking	4
2.2 Use as a Frequency Meter	5
2.3 Use as a tachometer and vibration analyzer	5
Section III General Theory	
3.1 General Design Features	8
Block Diagram of the system	8
3.2 The Tachometer Head	9
3.3 The Analyzer Unit	10
Section IV Maintenance	14
4.1 Normal Operation; Standardization	14
4.11 Linearity Test	14
4.12 Standardizing the Calibrating Oscillator	14
4.2 Abnormal Operation	16
4.21 Voltage Measurements	16
4.22 The Calibrating Oscillator	17
4.23 The Frequency Meter Circuits	17

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SECTION I

INTRODUCTION

1.1 PURPOSE

The Rotalyzer is a dual-purpose tachometer which not only measures speed but also variations in that speed. Cyclic variations can be viewed on an oscilloscope, or recorded, while non-periodic variations can be recorded on suitable recorders. It is useful for the study of torsional vibrations, hunting in motors and control systems, effectiveness of filters, vibration dampeners, and flywheels, etc. With the addition of suitable control circuits, it can be used for the precise control of speed.

1.2 SPECIFICATIONS

Tachometer Head: Standard model supplied with two different numbers of magnetized poles on the induction disc, to cover the speed range from 500 to 9,000 r.p.m. Special discs for other speed ranges can be substituted. Magnetized discs and pickup heads can be supplied separately for building into equipment to be studied in those cases where the standard tachometer head is unsuitable or cannot be coupled properly.

Circuit Unit (analyzer):

Range of input frequency: Nominal, 5,000 to 30,000 c.p.s. but can be used down to about 2,000 c.p.s with lower resolution.

Minimum input voltage required for operation: 10 millivolts. Input gain control to attenuate higher voltages, up to a maximum of about 100 volts. Not critical as to input voltage.

Input impedance, 100,000 ohms resistive.

Accuracy of speed (frequency) measurement, 0.5% of fullscale.

Output circuit for measurement of variations in speed; Output voltage, 1.5 millivolts per c.p.s. change of frequency. Output impedance, 10,000 ohms. Changes of speed occurring at rates in the range 2-500 c.p.s. will be shown as voltages at the output terminals. Frequency band of output circuits, 2 to 500 c.p.s. Can be extended down to d.c. by removing blocking capacitor. Upper limit can be changed by changing the filter unit.

Calibrator: a 10,000 cycle oscillator, deviable by 10, 30, 100, or 300 cycle increments, is included to permit calibration both of the average speed indications and of the variational indications. Deviation can be either in fixed increments or in square-wave modulation at a switching rate of 20 c.p.s. so that the calibration will pass through coupling circuits to the viewing or recording equipment.

Noise level at output terminals, less than 3 millivolts.

Power: 105 to 125 volts, 50 to 60 cycles, 40 watts.

Dimensions: Panel, $7\frac{1}{2}$ " wide x $11\frac{1}{2}$ " high, depth over knobs, 15".

Weight, 25 lbs.

Shock-mounting base for airborne use adds $1\frac{1}{2}$ " to height.

1.3 GENERAL DESCRIPTION

The complete Rotalyzer includes a sensing unit or tachometer head, a circuit unit or Analyzer, and an oscilloscope.

1.31 A tachometer head, or probe, is coupled to and driven by the shaft whose motion is to be studied. The tachometer head contains a small induction-disc a.c. generator having many poles, so that a high frequency is generated by its rotation. 600 poles is considered the standard number, since with this number, the c.p.s. of generated frequency will be just ten times the rotational speed in r.p.m. Thus, with the standard input frequency range of the Analyzer unit of 5,000 to 30,000 c.p.s., the measurable speed range becomes 500 to 3,000 r.p.m. For higher speeds, a smaller number of poles is used, while for lower speeds a higher number, which will usually require a larger diameter induction disc, will be required. The standard tachometer head is made with two pickup heads and two magnetized pole tracks on the disc, having 600 and 200 poles, so that it covers the speed ranges 500 to 3,000 and 1500 to 9,000 r.p.m. without change of discs.

1.32 The Analyzer is essentially a cycle-integrating frequency meter whose circuit design has been worked out so as to give it high accuracy and linearity of response, fast response to changes of input frequency, and the ability to indicate these changes as well as the average value of the input frequency.

An input gain control potentiometer is followed by two voltage amplifier stages and a regenerative amplifier so arranged as to give a square-wave output of constant amplitude, regardless of variations of amplitude at the input of the Analyzer. The output of the squaring amplifier triggers a pulse generator which generates one pulse for each cycle in the input wave. The energy in these pulses is integrated into a voltage which is accurately proportional to the frequency of the input wave, and to nothing else. The time constants in the integrator and following circuits are chosen to allow variations as fast as 500 c.p.s. to be followed. A low-pass filter removes components of carrier (input) frequency and passes only the variational frequencies to the output terminals.

A calibrating oscillator of high stability is provided, to furnish signals of known average frequency and known deviation, so that the analyzer and associated viewing or recording equipment may be calibrated as desired, for both average speed and variational speed indications.

A conventional line-operated power supply unit furnishes electronically-regulated plate voltage and unregulated heater voltage to the analyzer circuit vacuum tubes.



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1.33 The oscilloscope is a DuMont Type 304H, modified to provide one additional sweep frequency range at the low end, so that sweeps down to $\frac{1}{2}$ c.p.s. can be obtained.

SECTION II. OPERATING INSTRUCTIONS

2.1 Placing Instrument in Operation. Checking and Calibrating.

The following routine, or a simplified version of it, should be followed each time the instrument is placed in service, in order to make certain that it is operating properly and is in calibration so that the speed dial will read correctly.

Connect the instrument to the 115 volt, 50-60 cycle a.c. line by means of the cord set and twist-lock connector provided.

Operate the power switch to ON, whereupon the pilot lamp should light. If it does not, check the fuse, which is replaceable from the front panel. Use a 1 ampere fuse.

Allow 30 seconds for the vacuum tubes to warm up.

Set the RPM dial to zero. This is a 3-turn Helipot potentiometer which furnishes a voltage to balance the voltage developed in the cycle-integrator circuit. When the two voltages are equal, as shown by a balance reading on a vacuum-tube voltmeter fitted with a zero-center meter, the RPM dial gives a reading proportional to the input frequency.

Note: Since the scale of the RPM dial runs from 0 to 300, while the input frequency range is up to 30,000 c.p.s., it is necessary when reading frequency to add, mentally, two zeros to the reading of the Helipot dial. When measuring speeds, if the 600 pole disc is being used, it is necessary to add one zero to the dial reading to obtain RPM. For the 300 pole disc, multiply the dial reading by 20 to obtain RPM.

Set the METER RANGE switch at x 10, its lowest sensitivity range. The switch should always be left at this setting, to protect the meter movement against violent offscale deflections, between measurements or while making circuit changes.

Bring the meter to its zero-center position by means of the control marked ZERO ADJ. Check to see that it is possible to deflect the meter to either side of zero by this control; this checks the operation of the entire VTVM and balance meter circuit.

Set the DEVIATION control at 0 and the calibrator switch at ON, thus applying 10,000 cps from the calibrating oscillator to the frequency-counter circuits. The balance meter should immediately deflect to the left and indicate approximately fullscale. Turn the RPM dial to restore the meter to zero; turn the METER RANGE switch to x 1, which increases its sensitivity by a factor of 10, and refine the setting. The RPM dial should now read exactly 100, that is, .01 of the input frequency (See Note above)

If it does not, the calibration of the instrument should be adjusted by means of the CALIBRATE screwdriver control to be found in the access opening at the rear of the instrument. Set the RPM dial exactly at 100 and adjust the CALIBRATE control to bring the meter to zero. The RPM dial will now read correctly throughout its range.

Set the DEVIATION switch at 10 RPM and rebalance; the dial should now read 99 (990 RPM). With the DEVIATION switch at 30, the dial should read 97 (970 RPM), for the frequency of the calibrating oscillator has been shifted downward 300 cycles, to 9,700 cps.

Note: Deviations of the calibrating oscillator are always downward only, from the standard value of 10 kc. They do not resemble the symmetrical deviations found in FM radio.

Connect the vertical input terminals of an oscilloscope to the OUTPUT terminals of the Analyzer. This circuit is fairly low impedance and ordinarily no special shielding precautions will be required, except in the presence of strong r.f. fields. The oscilloscope should have excellent low-frequency response and sufficient amplification to produce usable deflections with inputs as low as 10 millivolts. Observe the trace to see if there are any ripple (hum) voltages coming from the Analyzer. If so, attempt to reduce them by means of the screwdriver control marked RIPPLE to be found on the access opening at the rear of the instrument. It should be possible to balance the ripple voltages down to less than 2 or 3 millivolts peak-peak.

Turn the CALIBRATOR switch to PULSED. A chattering sound should be heard, due to the vibrating action of the switching relay. Turn the DEVIATION switch to 1, whereupon a small square wave of about 15 millivolts p-p amplitude should appear on the scope trace. The repetition rate is about 20 cps.

Note: The duty cycle of the switching relay has been made considerably different from 50% in order to permit the observer to distinguish between the deviated and undeviated deflections. The longer portion is always the deviated value; the shorter time is that during which the frequency is returned to the undeviated, 10 kc, value.

Operation of the DEVIATION Switch to higher deviations will increase the amplitude of the output wave by factors of 3, 10, and 30. The small damped transient at the trailing edge of each transition is due to the sharp cutoff characteristics of the low-pass filter. It cannot be eliminated except by reducing the effectiveness of the filter, and this would allow ripple at the carrier (input) frequency to appear in the output.

This completes the operational check, and if the instrument has responded satisfactorily to all the above tests and adjustments, it is calibrated and ready for use. Otherwise, see SECTION IV, Maintenance.

2.2 Use as a Frequency Meter.

Since the Analyzer portion of the equipment is actually an accurate frequency meter, it can be used as such if desired. Connect a voltage whose frequency is to be measured to any one of the four input connectors, and set the INPUT SEL switch to connect it to the gain control, which should then be advanced until the meter deflects. Turn the RPM dial to obtain a meter balance, and read the frequency from the dial, mentally adding two zeros to the dial reading to get frequency in cycles per second.

Changes of frequency can be followed on the meter without using the RPM dial. Its ranges are as follows:

On the x 10 range, the meter reads	10,000 - 0 - 10,000 cps
" " x 1 " " " "	1,000 - 0 - 1,000 "
" " x .1 " " " "	100 - 0 - 100 "

Note that fullscale deflection of the meter on the x .1 range is greater than the rated accuracy of the entire instrument, 0.5% or 150 cycles. Drift and instability will be noticed when using this range, and will seriously limit its usefulness. It has been included only to permit greater resolution in certain special cases, and should not be used as a regular practice. Should it be used extensively, the inclusion of a line-voltage regulator in the power-supply system will considerably reduce the annoyance of the drifting which will otherwise be encountered. For all ordinary work, the x 1 range is the greatest sensitivity which should be used; it enables balance to be set to a degree considerably within the rated instrument accuracy.

Some idea of the relative scale spread can be obtained from the following figures:

The 0 to 30,000 cps range extends over 14" of scale on the 3-turn Helipot dial of the RPM control. 0.5% is .070", 1.5 dial divisions.

On the x 10 meter range, the 30 kc would extend over only about 2" of scale, so obviously this cannot be read as accurately as the RPM dial.

On the x 1 meter range, however, the scale spread is equivalent to a meter scale 20" long, so that settings on this range can obviously be made to the full accuracy of the instrument. 0.5% is .10"

The excess sensitivity, and the necessary care in use, of the effectively 200" of scale spread on the x .1 meter range need hardly be emphasized further.

2.3 Use as a tachometer and vibration analyzer.

In this application, the speed or velocity is first converted into an a.c. wave whose frequency is accurately proportional to the speed to be measured, and then this a.c. wave is fed to the Analyzer portion of the equipment. The steady component of the wave is a measure of the average speed, while any modulations or changes of

frequency will be due to changes, either fast or slow, in the speed, and can be analyzed to show up such variations. Analysis is accomplished by a process similar to that used in extracting the intelligence from a frequency-modulated wave, in fact, there is a close parallel between the Rotalyzer system and an FM transmission system. It will be helpful to keep this analogy in mind while studying the operation of the system.

The tachometer head, or probe, or sensing element, which contains the a.c. generator, must be carefully and precisely adapted to the mechanism which is to be studied. Any looseness or eccentricity in the mounting or coupling arrangements is sure to introduce speed variations as great as, and sometimes greater than, the ones to be studied. Under such circumstances no results of any significance can be obtained, as it is usually impossible to separate the desired effects from the undesired ones in observing the trace or record. Nothing less than mechanical perfection in the mounting and coupling means can be tolerated. Be especially wary of the familiar universal joint, or Hooke's joint. It is especially prone to introduce errors unless perfectly constructed and precisely aligned; even if the joint itself is perfect, it will introduce velocity variations if the two shafts are not in perfect alignment. And if they are, the joint is unnecessary.

The tachometer head supplied with the Rotalyzer has been designed to have very low inertia and low friction, insofar as consistent and possible in view of the conflicting requirement for precise construction and tight, shake-free bearings.

There will be some shaft systems which are of such low power, or whose physical layout is such, as to prohibit connecting the standard tachometer head. In such cases it will often be possible to build a generator disc and pickup head into the mechanism, and this has been done in some cases. The necessary components, together with suggestions as to how the adaptation may be made, can be obtained from Ray Electric Company.

Connect the tachometer head to the analyzer unit with coaxially shielded cables of suitable length. Any length up to perhaps 200 feet may be used, but care should be taken to see that the outside shield of the cable is connected to ground at both ends.

With the machine under test running, and having checked and calibrated the Analyzer as described in Section 2.1, the desired generator is selected and the GAIN control advanced to obtain a meter deflection, after which the speed reading is taken with the aid of the RPM dial as already described.

The oscilloscope connected to the OUTPUT terminals will display the characteristics of any variations of speed which may be occurring; its trace should be synchronized with the rotating frequency of the system under study, either by the internal synchronizing provisions of the oscilloscope or by a suitable external agency, to obtain stationary images. If the variations of speed are non-repetitive in nature, it will be necessary to record them by a suitable direct-writing or photographic recorder.

Appropriate calibration traces can be made to appear on the scope screen or on the record in order to permit measurement of the variations observed. Since the Analyzer circuits operate under amplitude-saturated conditions, they can respond to only one input at a time. It is therefore necessary to remove the input wave being studied, when using the calibrator, by turning back the gain control or switching to an idle input connector.

Slow variations of speed will show up on the panel meter, which can be placed in an appropriate sensitivity range to show the variations to best advantage. Never leave the METER RANGE switch in the x .1 position, and preferably not even in the x 1 range, when not actually making observations. It would be possible to protect the meter against violent offscale deflections by providing it with a shunt consisting of two germanium crystals, connected back-to-back, but this arrangement will seriously alter the linearity of response of the meter and so was not used in the standard instrument. It may be added by the user if linearity is not important to him. It will not, of course, affect the operation or accuracy of the RPM dial.

Should it be desired to study speeds below the 500 RPM nominal limit, it is possible to go down to perhaps 2000 cps (200 RPM) before the Analyzer circuits become a limiting factor. The lower limit is set by the cutoff characteristics of the filter which is included in the output circuits for the purpose of removing components of carrier (input) frequency while passing the variational components. Substitution of a different filter will permit changing this limit. However, for very slow speed it would be greatly preferable to use a larger disc in the induction generator, thus permitting the use of a larger number of poles. Special problems of this nature should be taken up with Kay Electric Company, who are prepared to recommend solutions and in some cases, to supply the needed equipment. Speeds down to 20 rpm can be measured by the use of large discs.

SECTION III

GENERAL THEORY

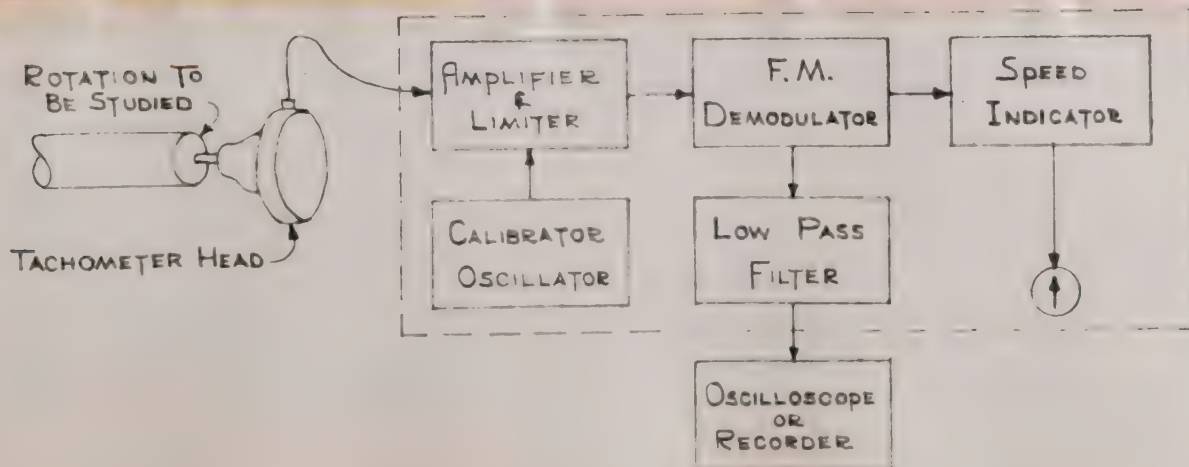
3.1 General Design Features.

The purpose of the Rotalyzer is not only to measure the speed of a shaft, machine, web, rolled product, etc., but also to detect and delineate variations in that speed. This it does by first converting the speed into a voltage whose frequency is exactly proportional to that speed, then analyzing the voltage for the two types of information desired. Unlike other tachometers which have only a small number of poles or contacts per revolution, the Rotalyzer uses a large number, 600 on the standard disc. This gives, in effect, many data points per revolution, and allows fine analysis of the motion within a single revolution.

Any shaft speed or other velocity can be considered as having two components, one of constant magnitude (the average speed) and the other containing all of the variations around that average, whether fast or slow. Note the analogy to the familiar frequency-modulated radio wave, which contains a carrier of constant frequency and modulation components containing all of the information. This concept will be employed extensively throughout this discussion; speed and FM terms will be used somewhat interchangeably.

The Rotalyzer measures the two components separately, giving a dial reading proportional to the average speed, plus a voltage which is accurately proportional to the variational components in the speed. This output voltage has a magnitude of approximately 1.5 millivolts per cycle per second change of frequency, and thus is of sufficient magnitude to permit viewing on a good oscilloscope or recording on suitable equipment.

The complete Rotalyzer consists of a sensing element or tachometer head which converts the speed into a frequency, an Analyzer unit which translates the frequency into the speed indication and the variation information, and an oscilloscope (furnished) or a recorder (not furnished) to delineate those variations against time as abscissa. The complete system is shown in block form:



3.2 The Tachometer Head

The heart of the Rotalyzer system is the small multi-pole induction disc generator contained in a tachometer head or sensing element driven by the shaft whose speed is to be studied. The standard disc is magnetized with 600 poles, so that in effect this many data points on the progress of the motion are taken during the course of each revolution. This permits the detection of small changes of speed (torsional vibrations, etc.) which occur at a rate faster than the rotational period of the shaft.

The standard disc operates in the speed range 500 to 3,000 rpm. For speeds outside of this range, a different number of poles will be used, but it is always chosen so as to yield a generated frequency in the high audio range, between 5,000 and 30,000 cps. The generated frequency is, of course, related to the rotational speed by the equation

$$\text{Generated frequency} = \frac{\text{Shaft rpm} \times \text{number of poles}}{60}$$

In the above, number of poles means poles of like sign, corresponding to the pairs of poles of ordinary power machine terminology.

Thus, when using the standard disc of 600 poles, the generated frequency in cps will always be exactly 10 times the rotational speed in rpm.

It is always desirable to have the generated frequency as high as can be accommodated by the Analyzer unit. Low frequencies will not give good resolution of small, fast changes of speed which may be due to the presence of high-frequency torsional vibrations, gear tooth irregularities, bearing looseness, or coupling backlash in the rotating system under study. In radio terms, the carrier frequency must be high compared to the modulation frequencies. It is preferable that the carrier (input) frequency never go below about 5,000 cps if high resolution is desired and variational components up to 500 cps are of interest. For applications where only slow variations are encountered, however, the circuits in the analyzer will operate down to about 2,000 cps, so that speeds down to 200 rpm can be studied using the standard tach head. The use of a disc with a larger number of poles is, however, highly desirable.

It is not possible to increase the number of poles without limit without also increasing the size of the induction disc. The 2" disc used in the standard head has a circumference of about 6", so that on the 600 pole disc, the poles are only .010" apart. Discs with poles more closely spaced than this have been made, but irregularities of pole spacing and the low output voltage which inevitably results from the smaller flux linkage with the pickup coils rendered their usefulness very doubtful. The only practical way of getting more poles is to increase the diameter of the disc, and for special purposes this is sometimes practical. A disc 12" in diameter, with the pickup head in contact with the rim of the disc, can be used down to 10 rpm. This is obviously a very special application but is mentioned to show the wide range of usefulness.

of the Rotalyzer principle.

The importance of proper mounting and coupling of the tachometer head to the system to be studied is so great as to warrant repetition at this point:

Only the most perfect mounting and coupling arrangements, completely free of shake, backlash, eccentricity, etc., are good enough to realize the full degree of resolution of which the Rotalyzer system is capable. Any irregularities in the coupling can introduce velocity variations at the generator disc of a magnitude equal to or greater than the small vibrations which are to be studied.

Never use the Hooke's joint type of universal coupling between the system under study and the tachometer head. Unless perfectly made, the universal joint introduces evils worse than those it purports to cure; even when perfectly made, it will introduce velocity variations unless the two shafts are in perfect alignment, and when this condition is met, the joint is no longer needed. If a flexible coupling absolutely must be used, the sylphon bellows type should be selected.

3.3 The Analyzer Unit.

The function of this unit is to measure frequency and to translate variations in the frequency into a voltage accurately proportional to the amount and sense of the variation.

Frequency can be measured by several different methods, to almost any desired degree of accuracy, but as is the case with most measurement techniques, precision and speed of reading are not compatible, and a compromise must be made between them. Since the speed-measurement accuracy requirements of most applications are not severe, the Rotalyzer was designed to use a system of only moderate accuracy but of considerable ease and convenience of use. Since the instrument already contains a circuit for producing a voltage accurately proportional to frequency (the R.M. demodulator of the block diagram), the average-speed indicating system was derived from this by the addition of a potentiometric balancing system. The accuracy of such a system depends only upon the linearity of the voltage being measured and upon the precision of setting and reading the balancing voltage, and in the present instrument a balance sensitivity and a potentiometer scale spread sufficient to realize the rated accuracy of 0.5% has been adopted. Actually, there is a potential balance sensitivity considerably greater than required; this finds use in another type of measurement.

Circuit description

An Input Selector switch permits connecting any one of four BNC connectors to an input gain control, whose chief function is to reduce the level of high voltages such as might be encountered when the Analyzer is used as a frequency meter with sources other

than the tachometer head. The circuits are not at all sensitive to moderate changes in the amplitude of the input signal, except at the extreme upper end of the frequency range.

Following the input level control are two voltage-amplifier stages employing pentodes. The coupling and bypassing capacitors are small, since flat response to low audio frequencies is not required. The third voltage amplifier stage is called a regenerative squaring amplifier, since its function is to generate square waves of constant amplitude, for all input signals over a certain minimum amplitude. It thus corresponds to the limiter in an FM receiver. It consists of two pentodes in a cross-coupled bistable multivibrator circuit; it is carried to one of its stable states when the input wave goes positive, and back to the other (resting) stable state when the input wave returns from its positive excursion. About three volts are required at the input of this stage to cause the transition; the second tube is switched completely on and completely off by the transition so that it executes square waves of constant amplitude. The output is differentiated into a series of triggers, one positive and one negative trigger for each cycle of the input wave.

The positive triggers are not used; the negative ones cause a one-shot (monostable) multivibrator, also using a pair of pentodes, to generate pulses. The result is a series of positive-going pulses, having a width of about 10 microseconds and a constant amplitude of about 200 volts, one being generated for each cycle of the input wave.

The energy in these pulses is fed to a resistance-capacitance integrator circuit whose time constant, connections, and clamping arrangements have been carefully worked out to enable it to deliver a positive-going voltage which is accurately proportional to the number of pulses per unit time, and which can vary rapidly enough to follow fast changes in the pulse rate.

The output of the integrator is brought to a lower impedance level by means of a cathode-follower stage; the large d.c. component due to the average speed is removed by means of a blocking capacitor, and then the ripple frequency components due to the carrier (input) frequency are removed with a low-pass filter, whose cutoff frequency is 500 cycles and whose impedance is 10,000 ohms. This is a three-stage filter having a rather sharp cutoff and high attenuation in the rejected region, and, like all such filters, it will generate a cutoff ring (damped wave train of cutoff frequency) whenever it is fed a wave containing sharp transients. This ring will appear whenever the square-wave deviation of the internal calibrator is viewed, but will seldom be of any consequence with signal waves due to any variations likely to be encountered in work with rotating machinery.

The cathode-follower stage is also used as one-half of the balance vacuum-tube voltmeter used for speed measurement. The other half of the dual triode is fed a voltage derived from an accurately linear 3-turn potentiometer, and a sensitive microammeter connected between the two cathodes indicates when the potentiometer voltage is just equal to the integrator voltage. This enables

the integrator d.c. voltage to be read in terms of a dial setting, and under proper calibration conditions, the dial thus directly indicates speed (average frequency). Calibration is accomplished by means of a screw-driver adjusted control which changes the width of the pulse generated by the P. G. stage, and thus varies the amount of energy per cycle fed to the integrator. Since the integrator and the voltage dial are both linear, bringing them to agreement at one point is sufficient to calibrate the entire scale.

The internal calibrating oscillator is designed for great stability, and its output frequency of 10,000 cycles can be relied upon to about 0.1%. It is of the inductance-capacitance type and operates at a very low level; output coupling is very small. Deviation of the frequency, for calibration of the variational output voltage, is produced by switching small inductances in series with the main inductance, so as to lower the oscillating frequency by a known amount. No reactance tubes or vacuum-tube switches are used; the switching is done by the low-resistance contacts of a relay, whose coil is fed from a resistance-capacitance pulsing circuit so that the relay opens and closes at about a 20 cps rate, thus switching the deviating coils into and out of the circuit. The frequency is thus instantly switched from its deviated value to the standard 10 kc value and back again, and a square wave of output voltage, modified only by the time constant of the integrator and the passband of the output filter, is delivered to the output terminals. Thus an absolute known amount of voltage is available for the interpretation of records made with the Rotalyzer, in terms of actual cycles deviation.

The meter has been provided with three ranges, of which the lowest in sensitivity is more or less of a protective device, the middle ($\times 1$) is the one to be used in all ordinary work, and the most sensitive is only for use in watching small, slow speed variations. Due to the low-resistance path which exists between the two cathodes of the VTVM when the highest sensitivity range is used, there will be an effect upon the amplitude of the variational voltages delivered to the output terminals. This range should therefore not be used when recording or making measurements of vibrations, as it will affect the deviation calibration.

There may be instances in which the blocking capacitor seriously alters the results, as in those cases where there are slow swings of speed to be recorded, in the region of 2 cps or below. Or, it may be desired to record changes of average speed, so that the d.c. component of integrator output is desired at the output terminals. In these cases, the blocking capacitor should be removed from the circuit, and placed instead in series with the 10,000 ohm filter terminating resistor, so as to prevent this resistor's being a d.c. shunt on the line. (such a shunt would draw enough d.c. through the filter coils to saturate them).

With the capacitor removed, there will now appear, at the output terminals, the variational voltages superimposed on a constant potential of about 12 volts due to the static current

of the cathode-follower, plus a voltage of approximately 1.5 millivolts per cycle of the input frequency. Thus, if the input voltage comes from a 600-pole wheel running at 1800 rpm, this component will be about $18,000 \times 1.5 \times 10^{-3} = 27$ volts, which added to the static voltage will be about 39 volts, about which value will appear the a.c. component due to variations of speed. The steady value can of course be bucked out by means of an adjustable battery connected in series with the output lead. Or, if it is possible to operate the recorder without grounding its low input terminal, the bucking potential can be obtained from the other cathode-follower tube, and be adjusted by means of the RPM dial. That is, the output can be taken across the meter circuit. Examination of the schematic diagram which is a part of these instructions will make the method clear.

SECTION IV

MAINTENANCE

4.1 Normal operation; Standardization of Calibrator.

The inclusion of the calibrating oscillator in the Rotalyzer makes it, when used in conjunction with the furnished oscilloscope or any other good oscilloscope, almost completely self-checking. If the schedule of tests outlined in Section II is successfully completed, the instrument is in satisfactory working order and can be used for measurements with full confidence.

There are two additional checks which should be made at intervals of a few weeks or months, and which require, in addition to the above, an audio voltage source whose frequency is known or can be set to a high degree of accuracy. The source should be capable of supplying a voltage between 10 millivolts and 1 volt at various frequencies in the audio range; if it is not crystal-controlled (the output of a secondary standard divider chain is ideal for the purpose) then there must be some provision for setting frequency to at least 0.1%, and preferably .01%. If no other method is available, recourse can be had to the audio tones transmitted by WWV. Oscilloscopic comparison of these tones with the local audio oscillator will permit this latter to be set at a limited number of spot frequencies with adequate accuracy.

4.11 Linearity Test.

Connect the output of the audio source, set for a voltage output between 10 mlv and 1 v, at a frequency of exactly 10,000 cps, to one of the input connectors of the Rotalyzer. Select this connector by means of the INPUT SEL switch and advance the GAIN control until the meter deflects. Set the RPM dial at exactly 100 and the meter range switch on x1. Adjust the CALIBRATE control at the rear of the instrument to make the meter read exactly zero center.

Change the input frequency to 20,000 cps and rebalance the meter; the dial should read within 0.5% (1.5 divisions) of 200. In the same manner check at a higher point such as 25 or 30 kc. The audio oscillator output voltage or the GAIN control setting may be found to have a slight effect on the reading at these very highest frequencies, above perhaps 250 on the dial. This is due to the fact that the pulse output of the pulse generator stage is becoming comparable in length to the whole input cycle, and there is a slight tendency for the positive triggers to shorten the pulse when the input is too high. The correct GAIN setting is that one which gives the greatest positive (left-hand) deflection of the meter, or the highest dial reading at balance. At lower frequencies, below 20 kc, changes of input voltage of as much as 100 to 1 should have no appreciable effect upon the reading.

4.12 Standardizing the calibrating Oscillator.

For this procedure, the chassis must be removed from the

cabinet. Remove the two binder-head screws to be found on the rear surface of the cabinet, and slide out the chassis. It will rest safely in any position; the normal one is suited for most purposes.

Only one standard frequency, 10 kc, is required for this, but its accuracy must be high, at least .05% and preferably .01%, since it is desired to set the 10 kc calibrating oscillator correct to about 0.1%. Connect to the Rotalyzer as in the above Linearity Test.

Set the oscilloscope sweep at exactly 10 cps, synchronizing it with the 60 cps line and adjusting so that just 6 of the 60 cps waves are shown on the screen. Remove the 60 cps test signal and connect the scope input to the grid of the third 6AU6 from the rear of the chassis, V3.

Set the DEVIATION switch to 0 and the CAL OSC switch to ON. A band of deflection with no individual cycles discernable will appear on the scope screen; its amplitude should be adjusted to about one inch. Slowly advance the GAIN control until beats between the calibrating oscillator and the standard are seen. Set the calibrating oscillator exactly on 10 kc by reducing the beats to zero by means of the slug-adjusted coil marked 10 KC ADJ. Lock the adjustment by means of the jam nut and do not change it during the remainder of the procedure.

Now turn the DEVIATION switch to 1 RPM, which should lower the frequency to exactly 9,990 cps. If so, just one stationary beat cycle will appear on the screen, for the scope sweep is at just the desired beat frequency. If the beat cycle drifts, adjust it to be stationary by the slug-adjusted coil marked A.

When the DEVIATION switch is turned to 3 RPM, three stationary beat cycles should be seen, or, if the scope sweep is readjusted to be 30 cps, one beat cycle will appear. Adjust for a stationary image by means of coil B.

To get the 100 cycle difference called for on point 10 of the DEVIATION switch, the scope sweep should be set at 100 cycles by being locked to a suitable audio source, or, if none is available, the scope sweep can be set at 20 cycles and locked to the line at one-third of line frequency, after which the image is adjusted to show five beat cycles, by means of coil C.

Similarly, to get the 300 cycle difference required on point 30 of the DEVIATION switch, the scope sweep can be synchronized at 300 cycles by a suitable source, for a singlebeat pattern, or can be locked at 60 cps by the power line connection and a five-beat pattern used. Adjustment by coil D.

Lock the adjustments by means of the jam nuts, recheck all points, then try the pulsing relay by operating the CAL OSC switch to PULSED. Using a slow scope sweep, the manner in which the frequency is switched between the deviated value, as shown by the beats, and the undeviated value of 10 kc will be immediately evident, as will the fact that the deviated value is held for the longer time and the 10 kc value for the shorter. Note: Do not readjust the

10 kc value under this pulsed condition. The slow beats which appear during the short, undeviated interval are not evidence of misadjustment of the 10 kc setting, but are merely apparent. They are due to the random starting phase of the 10 kc frequency as the relay contacts close. Any attempt to eliminate them would surely result in a misadjustment of the 10 kc oscillator.

Connect the oscilloscope to the Rotalyzer Output terminals and observe the rectangular output wave due to the deviated calibrating oscillator. Contact bounce, uncertainty, etc. will show up and the cause can be sought and adjustments made at this time.

4.2 Abnormal Operation

If, when placing the instrument in service and performing the checks and calibrations outlined in Section II, faulty operation is encountered, the following notes may be of assistance in locating and curing the trouble.

In general, the trouble shooting techniques usually found useful with other electronic instruments will serve best in working on the Rotalyzer. Voltage measurement, localizing trouble by sectionalizing, replacement of defective components, adjustment and recalibration is the suggested order of procedure.

In addition to the equipment already mentioned in these Instructions, a good volt-ohm-milliammeter will be required. It should preferably have a d.c. voltage sensitivity of 20,000 ohms per volt, and the readings given below are all in terms of that current drain. A. C. voltages, excepting in the power supply portion, should be measured with the oscilloscope.

If the pilot fails to light, check the connecting cord and the fuse. Replacement of the fuse should be of a 1 or 2 ampere 3 AG type. It is quite unlikely that the pilot itself would fail since this is of the glow type, but a voltage measurement inside the cabinet will tell the story. A good place to start is the 6.3 volt heater bus; if this is not right proceed back toward the power connector, until the fault is located. Persistently blowing fuses mean a short, probably on the high voltage system, or possibly in the transformer. Pull the rectifier tube to separate these two possibilities.

4.21 Voltage Measurements

The high voltage ahead of the regulator stage is about 375 volts to ground; the regulated voltage is 250, and is adjusted by a screwdriver controlled potentiometer located on the terminal board at about the middle of the chassis. The cathode potential of the 6AU6 amplifier tube in the regulator system, V12, is the reference potential, and is determined by the discharge voltage of the OA2 tube, V13. The grid of the 6AU6, V12, should measure about 2 volts less positive than its cathode; its screen is at 250, and its plate will be about 220, all to ground.

If either the 375 or the 250 volt bus has very low voltage, look for bad tubes or shorts. The filter capacitor is plugin and is always open to suspicion. The first filter capacitor out of the rectifier, however, is in a separate bathtub, and this too should be suspect. Shorts should be located by the usual sectionalizing methods. Should shorted coupling or bypass capacitors be found, it is well to replace also any resistors which were so located in the circuit as to carry the current drawn by the shorted capacitor, since the resistors are likely to have been overheated and changed in value.

Defective resistors or capacitors can be replaced with similar units of 5% or 10% tolerance. There are no critical values in the instrument except those marked on the diagram with an *; these affect the calibration and may possibly require selection in order to permit correct calibration.

4.22 The Calibrating Oscillator

If the supply voltages appear normal but the instrument still will not indicate when the calibrating oscillator is turned on, try applying a small (10 to 100 mlv) voltage of audio frequency (1 to 10 kc) to the input. If the instrument now gives indications, the trouble is in the calibrating oscillator, and not in the main frequency-measuring portion of the circuit.

The operating d.c. plate voltage of this tube, V9 is about 40 volts. When oscillating, a negative voltage of about 12 to 15 will appear on the grid. Grid to ground resistance, non-oscillating, should be 100,000 ohms; cathode to ground 40 ohms. This latter is of course the cathode choke coil.

There is no way of checking continuity of the 20 mhz main tuning coil in the hermetically sealed tuning assembly. Open circuits in the adjusting and deviating coils can readily be detected; if the "Coil" terminal of the tuning assembly be grounded, and the tube then oscillates, at somewhat too high a frequency, the trouble is definitely in the adjusting or deviating circuit. If, however, the tuning assembly itself is defective, it will be necessary to obtain a new one from the manufacturer. The operating voltage level is far below rating of any of the components in the sealed can, and they should have an indefinitely long life. If the oscillator operates but the circuit still does not respond to it, investigate the coupling circuit, which is by way of a small capacitor to the grid of the second voltage amplifier, V2. The capacitance is not critical, 3 to 5 mmfd.

4.23 Frequency-Measuring circuits.

Apply 10 mlv to the input and follow it through the circuit with the oscilloscope, noting whether the following voltages appear:

A. At the first tube grid, 10 mlv (Gain at max)

B. At the second tube grid, 100 to 200 mlv

C. At the third tube grid, 3 to 5 volts. The positive peak may be clipped and will show slight breaks if the stage is actually being carried through its transition region so that the pair turns over regeneratively.

D. At the plate of V4, square waves having a duty cycle of about 20 to 30%. The lower (quiescent) rail is about 40 volts positive; the peak goes to full supply voltage, 250 v, since the tube is completely cutoff. Changing the input voltage may change the duty cycle but it should not affect the amplitude; this pair of tubes should either work, or not work, with nothing in between. Partial or jittery operation should be remedied before proceeding, as it is essential that this stage generate exactly one positive and one negative trigger for each input cycle.

E. At the grid of V5, the triggers should be seen, superimposed on a d.c. level of about 15 volts. The negative triggers will be large, 30 to 50 volts, while the positive ones will be small, being limited by grid current in V5.

F. At the plate of V5, positive pulses starting at about 35 volts and rising to the full supply voltage of about 235.

G. At the plate of V6, negative pulses, just the reverse of those on V5. This tube is used only for its phase-reversing properties to make a pulse generator in connection with V5. Since positive output pulses are desired, the output connection is made to V5. V6, however, has one other important function, that of compensating for line voltage changes which affect the heater temperature. Its grid is left entirely unconnected, and under this condition it assumes a potential which depends upon heater temperature and thus compensates for changes in V5, which would otherwise affect the width of the generated pulse and therefore, the calibration of the instrument.

H. At the cathode of the clamping diode, the first half of V7, will be found pulses exactly like those on the plate of V5, but starting from a clamped level of about 6 volts positive. Note that the diode plate is returned to a potential of 6 volts, derived from the plate supply, while the discharge resistor is returned to ground. When the capacitance in the integrating circuit discharges after receiving a pulse, it heads for ground, zero potential, but never gets there, being "caught" at the 6 volt level by the beginning of conduction through the diode. Thus the lower 6 volts of the discharge exponential are never used; this has an important linearizing effect, particularly at low input frequencies where the discharge time is long compared to the charge time. Without this feature, it would not be possible to obtain a sufficiently linear response to meet the desired scale accuracy.

I. At the grid of V8 (active grid, pin #2) there will be found the integrated and partially smoothed output wave. At low frequencies, below say 1,000 cps, the individual discharges, terminating at the clamped level of 6 volts, can easily be seen. At higher

input frequencies, discharge does not become complete before another charge pulse is received, and the wave changes character and rises rapidly in d.c. level, about 3 volts per 1,000 cycles, so that at the highest input frequency of 30 kc, the d.c. level is about 90 volts. The ripple varies from about 5 volts at the low frequencies to perhaps a volt at the highest. A little study of these waveforms will reveal how the integrator is able to integrate properly, producing a d. c. level which is accurately proportional to the input frequency, and yet is able to follow fast variations in that input frequency.

J. At the cathode of the active portion of V8, pin 3, will be found an exact replica of the grid voltage, with a slight reduction in amplitude due to the less-than-unity gain of the follower, and with an added increment of about 12 volts d. c. due to the static bias of the stage.

K. At the grid of the balancing cathode follower, pin 7 of V8, will be found only d.c. voltages, depending upon the setting of the RPM dial. With this dial at 0, the voltage will be about 6, to balance the clamping level of the integrator. This voltage is set by the meter zero set control on the panel. As the RPM dial is increased in reading, the voltage will increase linearly to a maximum of about 90. The exact value is unimportant so long as the variation is linear. However, do not attempt to check linearity with the VOM--it takes a good precision potentiometer setup to detect errors in a Helipot wound to 0.1% linearity.

L. At the cathode of the balancing half of V8, pin 8, will be found the same voltage as on its grid, less the attenuation of the stage, and plus the static value of about 12 volts.

M. Tracing continuity through the low-pass filter and output system can best be done by applying the square-wave-modulated output of the calibrator, so as to get an audio signal, then following this through the system. The voltage is attenuated not only in the cathode-follower stage but also in the filter and its terminations, and the amplitude at the output terminals is consequently only about one-half of what it was at the integrator and grid of V8.

N. The resistance-capacitance network connected at the output terminals is a second integrator designed to give the output circuits a falling characteristic with frequency. Thus a voltage proportional to displacement, rather than to velocity, is developed. This network is removed from the circuit when the panel toggle switch is thrown to V, and under this condition the output voltage is proportional to velocity (frequency of the input wave.)

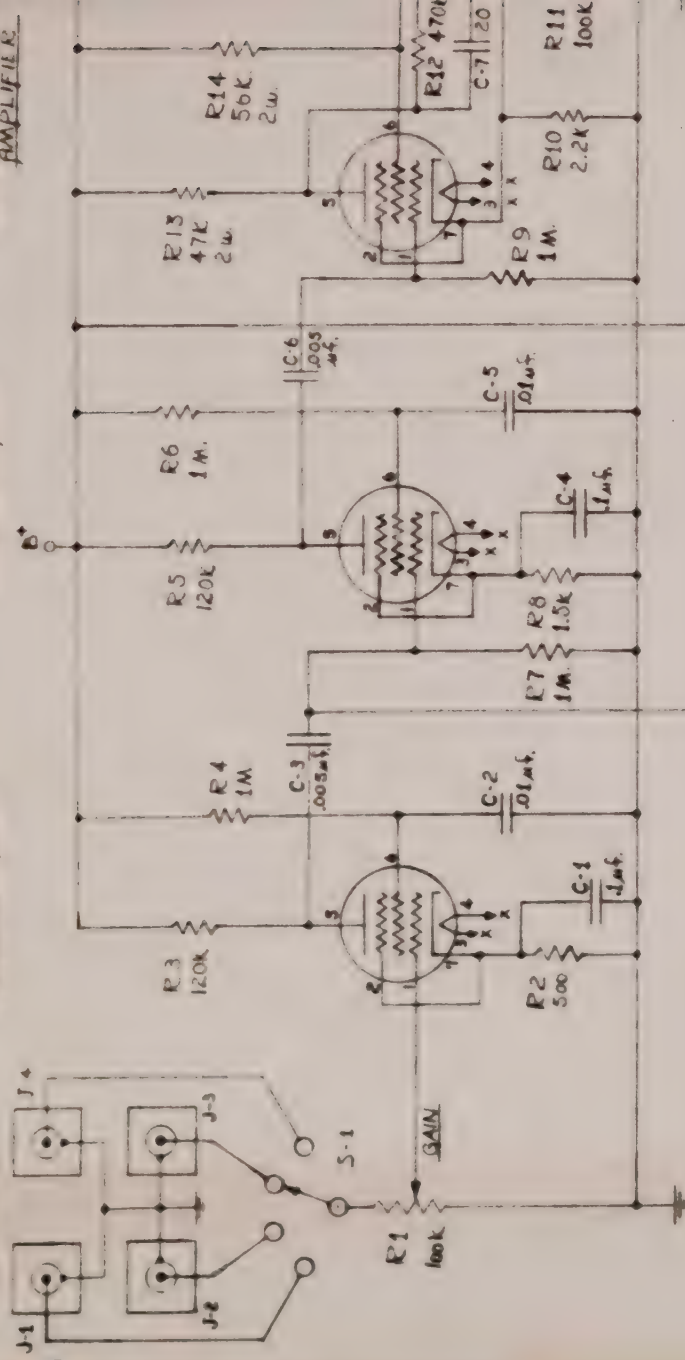
If the user encounters any difficulties which cannot be overcome with the aid of these Instructions, he is invited to correspond with Kay Electric Company. Servicing and repairs will be undertaken by this company upon request, but permission to return equipment to the company should be obtained before shipping it.

V-3 6AU6
REGULATIVE
AMPLIFIER

V-2 6AU6
VOLTAGE AMP

V-1 6AU6
VOLTAGE AMP

INPUT



Y-10
5Y3

V-11
6Y6

V-12
6AU6

T-1

T-2

T-3

T-4

T-5

T-6

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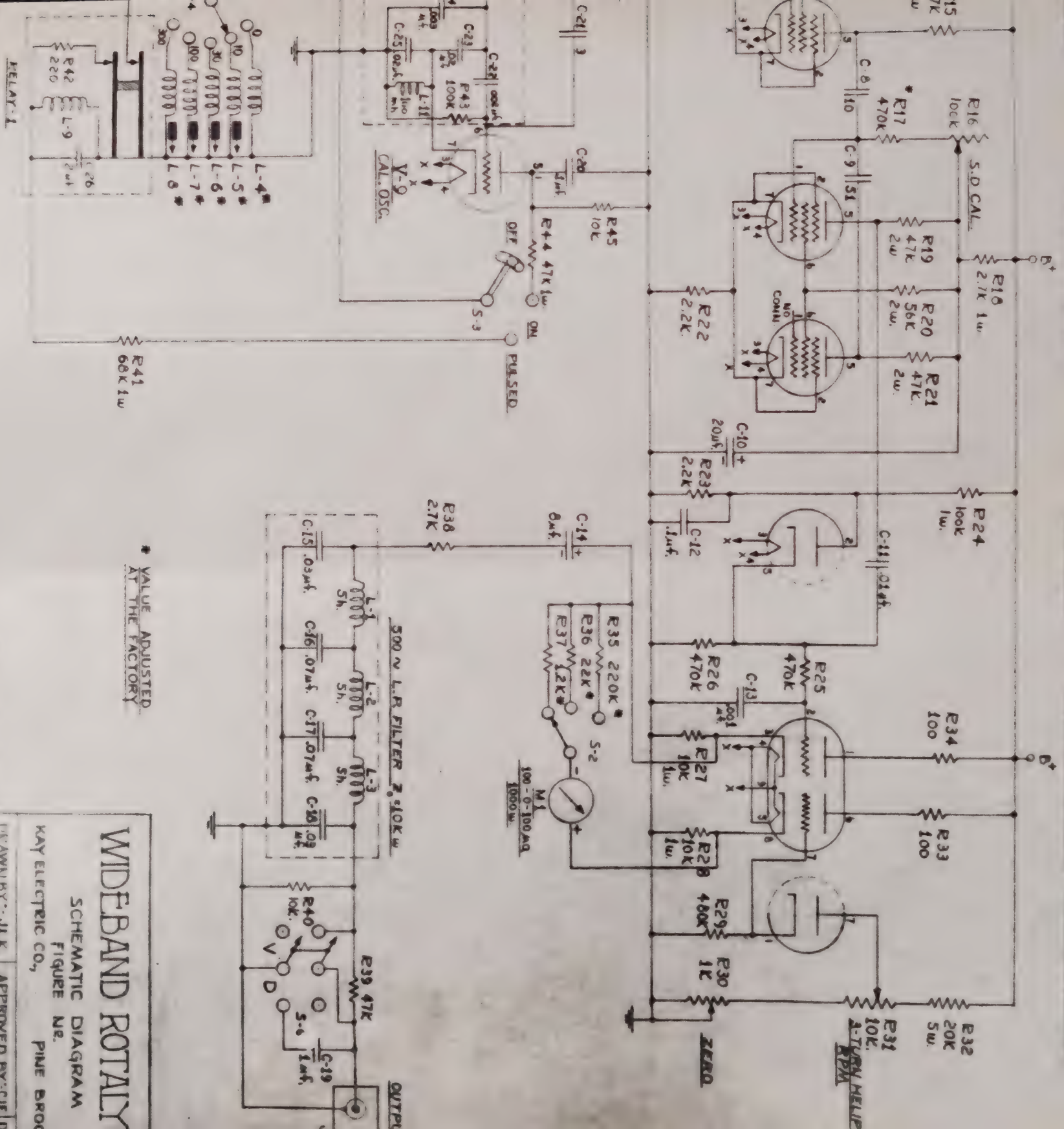
T

4
RING
Y-5 6AU6 Y-6
PULSE GENERATOR

Y-7a 1/2 6AL5
CLAMPER

Y-8 12AT7
CATHODE FOL. OUTPUT

Y-7b 1/2 6AL5
CLAMPER BALANCE



WIDEBAND ROTARY

SCHEMATIC DIAGRAM
FIGURE NO.
KAY ELECTRIC CO., PINE BROOK

DWG. NO. E034-A
DRAWN BY: JLK
APPROVED BY: CJF
OCT



77038